# AN ANALYSIS OF PHOTOGRAMMETRY APPLIED TO RIGHT-OF-WAY SURVEYS

AUGUST 1961

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Joint Highway Research Project

by

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PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

AN ANALYSIS OF PHOTOGRAMMETRY

APPLIED TO RIGHT-OF-WAY SURVEYS

TO: K. B. Woods, Director
Joint Highway Research Project

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

August 9, 19[illegible]

File: 3-[illegible]-17

Project: [illegible]-36-[illegible]

Attached is a final report on [illegible] to Right-of-Way Surveys by Phillip F. Southern, [illegible] on our staff. The research was performed under the direction of Professor R. D. Miles and was [illegible].

This report discusses the procedure of [illegible] maps and descriptions for the acquisition of [illegible] double projection plotter of the type used in the Indiana State Highway Commission was used in the compilation, and [illegible] with data obtained by the Right-of-Way Division.

The report is presented to the Board for the record.

Respectfully submitted,

H. L. Michael, Associate Director
Joint Highway Research Project

HLM:ow

Attachment

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Final Report

AN ANALYSIS OF PHOTOGRAMMETRY

APPLIED TO RIGHT-OF-WAY SURVEYS

By

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August 9, 1961

## ACKNOWLEDGMENTS

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The author wishes to express his most sincere appreciation to his major professor, Robert D. Miles, for his assistance and encouragement during the preparation of this thesis.

Special thanks are due William Prescott, Stereoplotting Engineer for the Indiana State Highway Commission for his aid and help in performing this study. Thanks are also due the Right-of-Way Division and the Photogrammetric Section of the Indiana State Highway Commission for their co-operation and assistance.

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# ABSTRACT

Scudieri, Philip Frank, MSCE, Purdue University, August 1961. An Analysis of Photogrammetry Applied to Right-of-Way Surveys. Major Professor: Robert D. Miles.

Right-of-way surveys are time consuming and expensive, and are often the cause of extended and unnecessary delays in highway construction. It is believed that the science of Photogrammetry offers a possible time and money saving solution to this problem.

This thesis reports the results of an application of photogrammetric methods in the preparation of maps and descriptions for the acquisition of highway right-of-way. The photogrammetric study is limited to the available plotting equipment at Purdue University, namely the standard six-inch focal length, double projection Kelsh Plotter.

A project area was selected that had previously been surveyed by conventional methods by the Indiana State Highway Commission. The proposed highway right-of-way lines were obtained from the construction plans provided by the Indiana State Highway Commission. The centerline of the proposed highway had been marked on the ground in a manner such that it could be accurately determined on the aerial photographs. This made it possible to photogrammetrically plot the existing property lines relative to the proposed highway right-of-way lines. It was then a matter of scaling from the base manuscript the required information necessary for the right-of-way acquisition.

The results of this experiment showed that the photogrammetric determination of the various parcel areas to be acquired was in close agreement with the parcel areas determined by the Indiana State Highway Commission methods. This project also indicated a close agreement between the photogrammetric and Indiana State Highway Commission determinations of data on which the right-of-way descriptions were based.

This limited project seemed to indicate that photogrammetric methods were applicable to the preparation of maps and descriptions for the acquisition of highway right-of-way.

# AN ANALYSIS OF PHOTOGRAMMETRY APPLIED TO RIGHT-OF-WAY SURVEYS

## INTRODUCTION

### Photogrammetry

Photogrammetry is defined as "the science or art of obtaining reliable measurements by means of photography" (1).* The photography used may be either terrestrial photography or aerial photography. Aerial photography is used most extensively in the applications of photogrammetry to highway engineering, and is used in this thesis project.

The acquisition of right-of-way for highway construction is both time consuming and expensive. It is believed that the science of Photogrammetry offers a possible solution to this problem. At present, all data necessary for the acquisition of right-of-way is determined by the Indiana State Highway Commission by ground surveying methods. This requires that all information necessary for right-of-way surveys be determined by three or four man field surveying parties. All data is placed in a field data book and, at some later date, is interpreted by a draftsman and drawn into right-of-way plans. Photogrammetry may possibly eliminate much of the field work and manpower required because the pertinent data can be plotted directly onto the base manuscript by a single plotter operator.

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* Numbers in parentheses refer to the Bibliography.

## Purpose

It is the purpose of this thesis to investigate applications of photogrammetry in the development of right-of-way surveys. This is to be accomplished by comparing right-of-way data obtained by photogrammetric methods with data obtained by ground surveying methods. The photogrammetric plotting is to be performed using the double projection, six-inch focal length Kelsh Plotter.

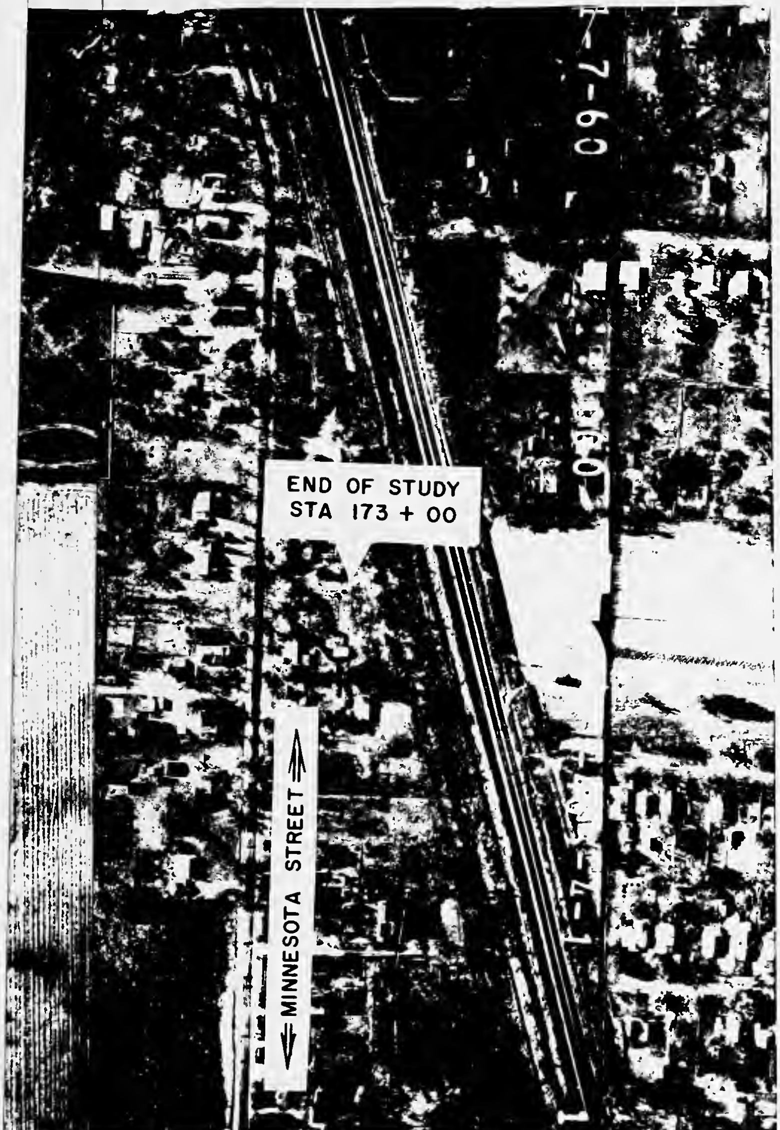
## Scope

The selection of the site involved the consideration of certain factors. It was considered necessary to obtain a site which had previously been surveyed by the Indiana State Highway Commission. This was necessary so that comparisons could readily be made between data obtained photogrammetrically and data obtained by field surveying procedures. The use of a previously surveyed area also helped minimize the amount of field work required.

It was also considered desirable to select a site that exhibited both urban and rural characteristics. A comparison could then be made to determine if the photogrammetric procedures might possibly be more applicable to one or the other of these areas.

After discussion with several members of the staff of the Right-of-Way Division of the Indiana State Highway Commission, a site along Indiana State Highway project 465-4 southwest of Indianapolis was selected. The section had a total length of slightly over one mile. A flight line mosaic of the study area is shown in figure 1.

Several studies were undertaken as a criteria for analyzing the applications of photogrammetry in right-of-way surveys. These studies




GHT


FLIGHT LINE MOSAIC OF STUDY AREA

FIGURE 1

included a comparison of data obtained photogrammetrically with the same data obtained by ground surveying methods. These data included certain areas, distances, and centerline stations pertinent to right-of-way descriptions. The various areas determined were: 1) the area needed for acquisition, 2) area remaining after acquisition, and, 3) total area owned.

The Indiana State Highway Commission uses two methods of writing deed descriptions for the acquisition of highway right-of-way. One method consists of describing all of the property as being measured from the centerline of the proposed highway. An example of this type description is shown in figure 2 for the property shown in figure 3. When condemnation proceedings are filed for a particular property, the second method of description is used. This method consists of describing the property to be taken by metes and bounds, that is, by giving bearings and distances along the boundary of the property.

It was not feasible to compare each deed description prepared by field survey methods with the deed descriptions for the same area prepared by photogrammetric methods. The reason for this was that at the time this report was written the Indiana State Highway Commission had not completed all the deed descriptions. The data from which the deed descriptions would be written were available. It was, therefore, possible to compare these data with photogrammetrically obtained data.

Form I.C.-120-BP
Purchase Grant—
LIMITED ACCESS
Revised—8-54

PARCEL NO 8

**STATE HIGHWAY DEPARTMENT OF INDIANA**
STATE HOUSE ANNEX
INDIANAPOLIS 9, INDIANA

**RIGHT OF WAY GRANT**

FUND I

PROJECT No. 465-4

SECTION (I) 153

This indenture witnesseth that the undersigned, as grantors and sole owners of land in MARION County, Indiana, more definitely described below, through, over and upon which will pass a public highway which it is proposed by the State of Indiana to improve, hereby grant, bargain, warrant and convey to the State of Indiana, for Right of Way, lands as described below and located by surveys and shown on plans on file in the office of the State Highway Department of Indiana. The description from said plans of said right of way hereby granted is as follows:

PLANS ON SR. NO. I-465 SEC. ______, I PROJ. No. 465-4 SEC. (I) 153 DATED 1960

SEC. 24, T. 15 N, R. 2 E 7.76 ~~SQ. FT.~~ ACRES, MORE OR LESS, ACQUIRED

Descriptions are of parcels of land lying between the plan centerline and the plan right of way line on the above designated project.

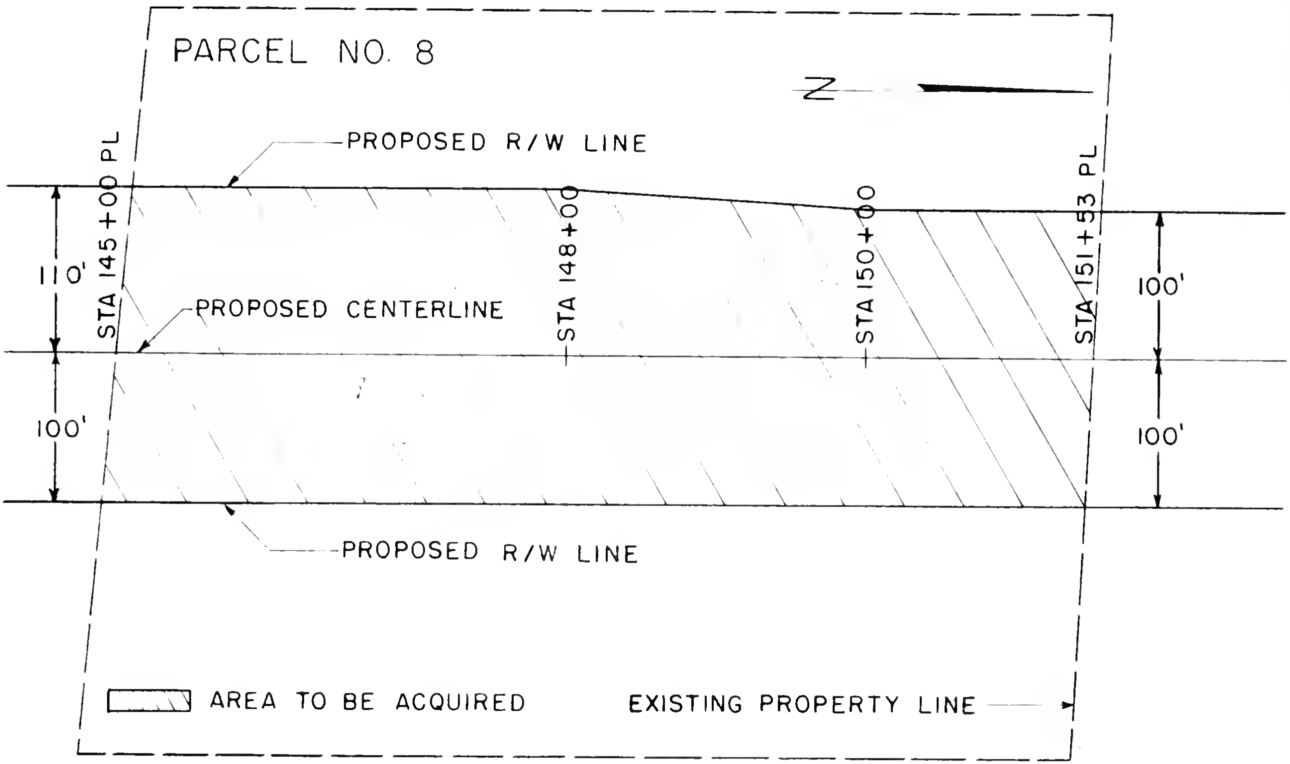
Measured distances along plan centerline are indicated by Station Number and plus.

Widths of parcels are indicated in feet, measured at a right angle from plan centerline at designated Station Number and plus; however, when Station Number and plus is followed by the letters P.L.; F.L.; F.D.; L.L. or C/L.S. (indicating property line, Fence Line, Field Division, Lot Line and Centerline of Stream respectively) or other identifying notations, it shall mean that the boundary line follows said identified line from plan centerline to plan right of way line.

| FROM STATION to STATION ON CENTERLINE (C/L) N | LEFT SIDE OF CENTERLINE | RIGHT SIDE OF CENTERLINE |
|---|---|---|
| 145+00± PL to 148+00 | 110 feet | 100 feet |
| 148+00 to 150+00 | 110 to 100 feet | 100 feet |
| 150+00 to 151+53± PL | 100 feet | 100 feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |
| to | feet | feet |

SAMPLE RIGHT-OF-WAY DESCRIPTION BASED ON CENTERLINE

FIGURE 2




SAMPLE PROPERTY FOR ACQUISITION

FIGURE 3

## PREVIOUS INVESTIGATION

European surveyors were using photogrammetry for cadastral surveying as early as 1931 (2). Today, photogrammetry of the highest precision is used routinely, especially in Switzerland and Austria.

In the United States, the application of photogrammetry to cadastral surveying has received relatively little attention. One experiment in this regard has been performed under the direction of J. E. King, Chief, Cartographic Section, Division of Engineering, United States Forest Service (3). The United States Forest Service has the responsibility of managing and administering 180,000,000 acres of national forest lands. Within the national forest lands there are 250,000 miles of property boundaries. Because of the urgent need for accurate and adequate property line determination, restoration, and perpetuation, the Forest Service has been actively engaged in developing and putting into effect a practical and acceptable method of photogrammetric cadastral surveys. The Forest Service feels that photogrammetry represents a method for efficiently and economically resolving the increasing problems of land ownership which now exist (3).

The only reported application of photogrammetry by a highway department in the preparation of right-of-way maps and deeds was a project performed by the Texas Highway Department in the Dallas District in 1958 and 1959 (4). The Texas Highway Department during this period prepared right-of-way maps and deeds from information furnished by aerial photogrammetric engineers. Private photogrammetric companies contracted to

compile the photogrammetric information. The companies furnished maps showing both planimetric and topographic details to certain specified requirements. Basically, the requirements were for maps to be compiled by photogrammetric methods at a scale of one-inch equals 20 feet. The horizontal accuracy requirement was specified so as not to exceed 0.5 feet of true distance, and the vertical accuracy requirement was to be within 0.3 feet of true elevation. These projects were performed using universal type photogrammetric plotters.

The first contract was performed in 1958 and pertained to a highway in an urban area with the strip varying in width from 1200 to 2400 feet. The 2400 foot sections were used for interchange areas. The 1200 foot sections were used in non-interchange areas. Experience indicated the 1200 foot sections to be unnecessarily large, and, on a later contract, the width was reduced to 760 feet. This represented a considerable saving.

In addition to the planimetric details for right-of-way studies, the map also showed contour lines. The Texas Highway Department felt that these topographic maps were well worth the additional expense because of the cross-section and drainage data that could be obtained without field surveys (4).

Illustrative of the savings both in time and money, the Texas Highway Department sited the following example in their August 1960 issue of Texas Highway Magazine:

> "On a one-mile section through a heavy residential area in the city of Dallas, the Department spent about $18,000.00 and nearly one year of surveying and drafting time developing a map (scale 1" = 40') showing both topographic and planimetric details. In our first aerial contract we received the planimetric and topographic maps covering a 2.5 mile section through the same type of residential area only four months after the contract was awarded. The cost - $12,000.00 per mile. These

> maps actually showed three times as much detail as the maps prepared by the conventional survey. With these brief statistics we might say that through photogrammetry the Department realized a saving of approximately 30 percent in cost, 800 percent in time and obtained three times as much detail. It is our firm opinion that these features are located more accurately by photogrammetry than by our usual field methods. We consistently had less trouble relating property lines to physical features such as fences and building lines." (4)

The above paragraph pertains to the planimetric and topographic maps as the Texas Highway Department receives them from the aerial contractor. After receiving these maps, the Texas Highway Department personnel make a field edit and note the type and condition of each improvement on a print of the planimetric map (4). There are two reasons for doing this: first, to check for omissions of improvements; and second, for future reference when making economic studies in determining the right-of-way acquisition.

The Texas Highway Department prepares a preliminary right-of-way plan to assist the title company in their project of furnishing the department with a copy of each property owner's deed. The department accomplishes this by obtaining photographic copies of maps and plats of official recorded subdivisions from the county clerk's office, as well as prints of the county plats of each survey or city block through which the new project is to be developed. The information is then assembled into a preliminary or tentative right-of-way plan for the abstract or title company's convenience. It may be added, that the above mentioned plats also furnish a good check on the photogrammetric dimensions of each block and also help verify the owner's deed (4).

After all the ownership data are acquired from the title company assigned to a given right-of-way project, the block lines and street rights-of-way are developed. There are two methods of accomplishing this:

> The first method is that of calculation. This method is used in urban areas where surveyors have actually established and marked the street intersections, and where the coordinates of each block corner have been computed. The distances between each corner are then checked against each owner's deed and the official plat. If there is no appreciable discrepancy within a given block, the lot lines and property lines are then plotted on the planimetric maps (4).
>
> The second method of developing the property lines is by careful scaling of the prepared maps. It is necessary to resort to this method in areas where surveyors have never established or marked the street intersections. In this method the planimetric sheets are carefully taped to the adjoining sheet to form a map of a good portion of the whole project. The block lines and lot lines are then plotted on the map. If appreciable discrepancies occur, the Texas Highway Department then has to resort to field surveys. It is stated that the department feels the assembled planimetric maps are not a wasted effort when these discrepancies occur as they have proved very helpful in giving the field party a comprehensive view of the area to be surveyed (4).

After all of the property has been developed on the planimetric sheets, these maps are placed over a roadway layout. This layout shows the geometric design, slope and ditch lines, and, as well as possible, retaining wall locations. The overlay is then carefully studied to determine the most economical and beneficial type of location and improvement. In cases where items of major right-of-way expense are involved, the economic studies are made by both engineers and appraisers. After these studies have been performed, the right-of-way lines are drawn on the planimetric property map in a location to provide the necessary right-of-way width to accomodate the proposed construction.

> "The exact location of the intersection of each property line with the right-of-way is determined by scaling a distance to the outside corner of each property and subtracting this set distance from the total dimension called for in the owner's deed." (4)

> "The deed descriptions are written to clearly define the property to remain and should the owner desire to have his remainder surveyed, we feel it could only affect the location of our right-of-way line a maximum of six inches." (4)

The Texas Highway Department has developed deed descriptions for over 1000 parcels of land by photogrammetric methods, and have acquired over 600 of these without having encountered any major problems (4).

# EQUIPMENT

## Aerial Camera

The aerial photography for this study was made by the Indiana State Highway Commission using a Kargl modified K-17 precision aerial camera. The distortion characteristics for this camera were obtained from a report by the National Bureau of Standards and are summarized in figure 4 (5). Figure 4 also shows distortion curves referred to the equivalent focal length and calibrated focal length respectively.

The camera uses a Bausch and Lomb Metrogon Lens with a nominal focal length of six inches and a maximum aperture of f/6.3. The equivalent focal length and the calibrated focal length are 153.25mm and 153.20mm respectively.

## Surveying Equipment

The vertical control for this project was established with the use of a self-leveling level. This level had a compensating pendulum prism which (after only minor adjustments) allows it to automatically set its own level sight. Considerable time saving was realized by the use of this type of level.

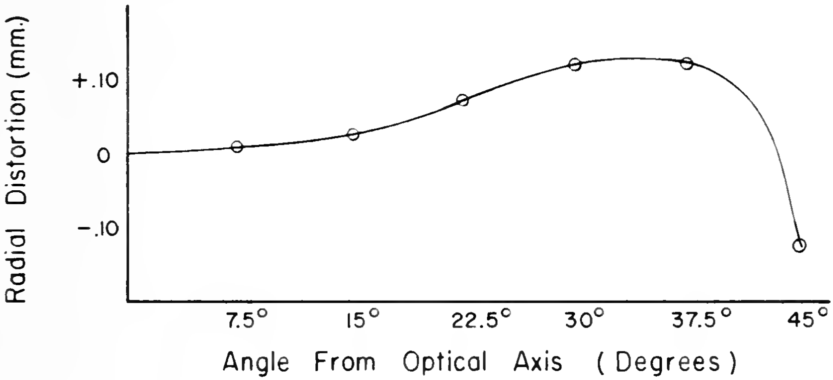
The centerline check and horizontal control were established with the use of a 20 second transit and a standard 100 foot steel chain.

## Kelsh Plotter

The photogrammetric plotter used in this study is the standard six-inch focal length Kelsh Plotter. The plotter uses an optical dichromatic

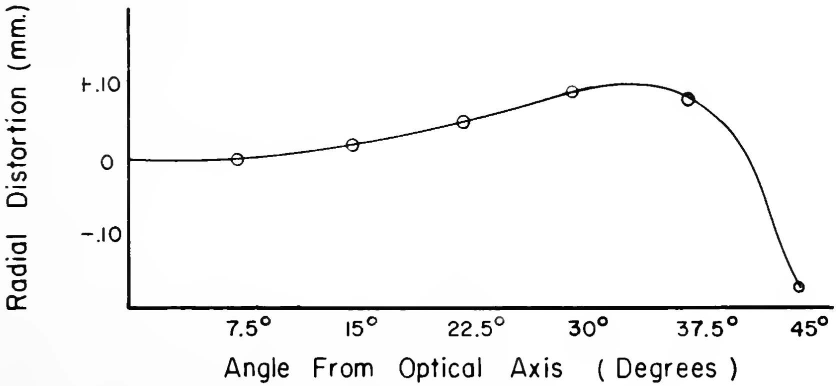
DISTORTION REFERRED TO THE CALIBRATED FOCAL LENGTH[5]

| 7.5° | 15° | 22.5° | 30° | 37.5° | 45° |
|---|---|---|---|---|---|
| 0.01 | 0.03 | 0.07 | 0.12 | 0.12 | − 0.12 |




DISTORTION REFERRED TO THE EQUIVALENT FOCAL LENGTH[5]

| 7.5° | 15° | 22.5° | 30° | 37.5° | 45° |
|---|---|---|---|---|---|
| 0.00 | 0.02 | 0.05 | 0.09 | 0.08 | −0.17 |




RADIAL DISTORTION CURVES

Figure 4

projection system. The viewing system is based on the anaglyph principle. In this system, narrow beams of red and blue monochromatic light are projected through 0.06-inch glass diapositives and the projector lenses to the platen of the tracing table. The platen is then raised or lowered to focus the two independent images. By viewing the images through spectacles having filters of the corresponding complimentary colors, a three-dimensional model is perceived. The plotter incorporates a series of correlated parallelograms such that a floating mark, centered on the platen, can provide a means of measurement within the stereoscopic model. The relative vertical motion of the floating mark with respect to the model is obtained by raising or lowering the platen, and this motion is measured by means of a height-indicating scale. Horizontal motion is obtained by sliding the tracing table on which the platen is mounted along the map surface; this motion is recorded by means of a pencil mounted directly below the floating mark. A double projection plotter of this type is not readily adaptable to bridging of control from model to model. For the most part, this is not a serious problem in large scale highway projects because the ground control used in establishing the centerline is usually already available. The orientation procedure of the photogrammetric plotter can basically be divided into three parts.

## Interior Orientation

Interior orientation is the procedure of adjusting the glass diapositive to a position on the plotter projector that will allow the cone of light rays emanating from a projector station to be essentially identical to the cone of rays that entered the camera lens at the instant of exposure. This is accomplished when the geometric relationship of the emulsion surface of the diapositive to the perspective center of the projector lens is equivalent to that which existed between the corresponding negative and the camera lens. The geometric

relationship is achieved by alignment of camera collimating marks with calibrated plate holders.

## Relative Orientation

The purpose of relative orientation of the plotter projectors is to reconstruct the same perspective condition that existed at the time the stereoscopic pair of photographs were exposed. Reconstruction is achieved by a systematic procedure of rotational movements to the projectors. Images are observed on the platen of the tracing table until conjugate images are made to coincide over the entire model area. There are two general methods of obtaining relative orientation. The one projector method and the "swing swing" method. The one projector method is applicable only to those plotters equipped with Y and Z motions. The "swing swing" method is applicable to all plotters. The plotter for this project does not have a Z-motion therefore the "swing swing" method of orientation is used (1). In this method the Y-parallax is observed at five points per model and is cleared by making swing, Y-tilt, and X-tilt adjustments of the projectors for each point observed.

## Absolute Orientation

The stereoscopic model formed upon completion of the relative orientation has an unknown scale and an undetermined relationship to the horizontal and vertical datum. The absolute orientation process relates the scale and horizontal position of the model to the horizontal control plotted on the vertical datum and also adjusts the plane of the model so that it is parallel to the reference surface. The two adjustments referred to are more commonly termed "scaling the model" and "leveling the model", respectively.

# PROCEDURE

## Centerline Check

The project site was surveyed by the Indiana State Highway Commission approximately three years ago. Because of the possibility of the stakes having been disturbed during this time lapse, it was necessary to check the distances and alignment of all centerline stakes in the project area. It was very important to have these stakes accurately located because they were to be used as the basis for establishing horizontal control. The check and replacement of the centerline stakes was accomplished by utilizing the construction plans provided by the Indiana State Highway Commission. A three man survey party replaced and checked the centerline stakes in approximately seven hours.

## Horizontal Control

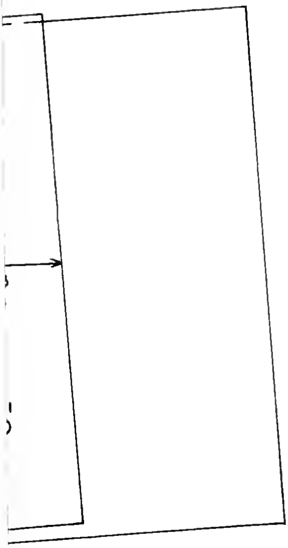
The Kelsh Plotter requires horizontal control for each stereoscopic model. The horizontal control is necessary in the absolute orientation procedure to establish an accurate scale for the plotted manuscript. Basically, to establish the horizontal control it is necessary to target certain ground points along the centerline of the proposed highway such that these points can be readily identified on the aerial photographs and on the corresponding diapositives. The distances between these points are also determined. These points are used both to establish the base line (also the proposed centerline) and to identify the horizontal control points on the base manuscript.

It was important to keep the number of targets required to a minimum. It was estimated that in order to have at least the minimum required two ground control points in each stereoscopic model the targets could be placed a maximum of 675 feet apart. However, because of inconsistencies of flying speed and of elevation of the aircraft and because of lack of definition and clearness due to distortion at the edges of air photographs, it was decided that the targets would be placed a maximum of 500 feet apart on the centerline of the proposed highway.

There were several cases in which the targets were placed less than 500 feet apart. It was necessary to avoid areas in which there was a possibility of the targets being disturbed. It was also essential to avoid areas where the targets would not be visible on the aerial photographs. A diagram showing the arrangement of targets used both for horizontal control and for establishing the base line is shown in figure 5.

Targets of several different sizes and shapes made of white muslin were used. The dimensions and shapes are shown in figure 6. Those targets used to designate the proposed centerline were all of the same size and shape, and were made by forming a cross consisting of strips five feet in length by six inches in width. Slits were cut in the middle of each strip of cloth so that they could be slipped over the centerline stakes. They were then weighted down by rocks. It was important to cut all brush in the vicinity of the flagged area flush with the ground so that the targets would lie as flat as possible and also so that no shadows would be cast.

The accuracy of the photogrammetric base map can be no greater than the accuracy of the target placement on the ground; therefore, it is



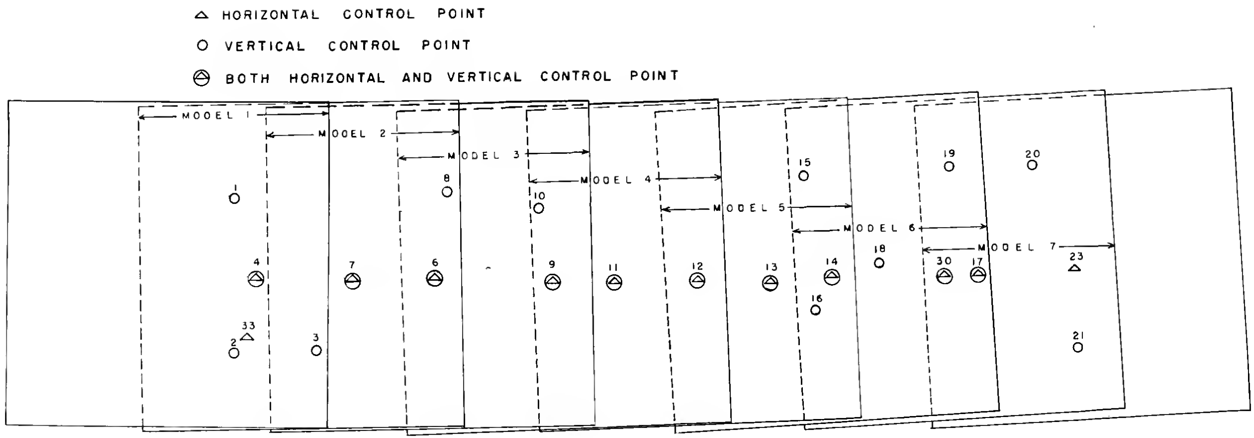
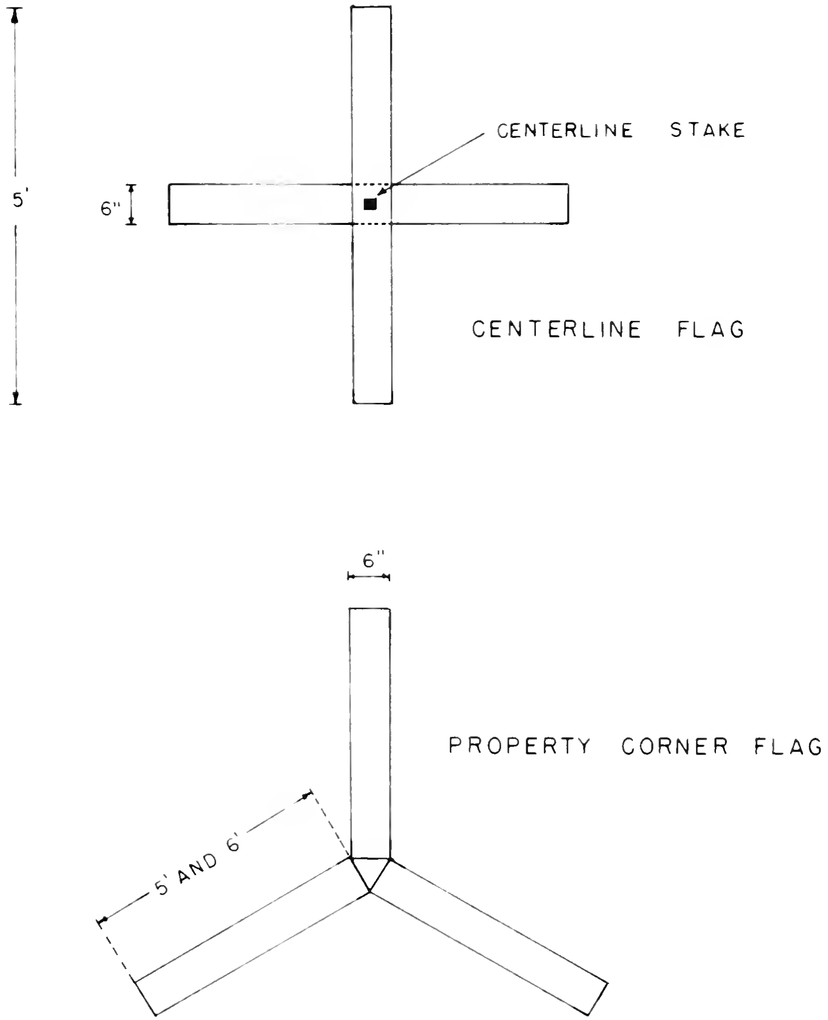



PHOTO POINT CONTROL

FIGURE 5




TYPES OF GROUND CONTROL TARGETS

FIGURE 6

extremely important to place the targets in their proper positions. The accuracy of the base map can also be no greater than the accuracy of the measurement of the image of the target obtained on the aerial photographs. Since the image clarity is dependent upon the size and shape of the target utilized, it is important that the proper size and shape of target be used.

## Aerial Photography

Aerial photography of the project area was obtained by the Indiana State Highway Commission on November 28, 1960. The photography was taken from an altitude of 1,500 feet above the average ground elevation. This altitude provided a contact photo scale of approximately one-inch equals 250 feet and a manuscript plotting scale of one-inch equals 50 feet.

The diapositives were prepared on 0.06-inch sensitized glass plates printed with the emulsion side up. The diapositives were generally of good quality. One model, however, could not be oriented stereoscopically. This was due to the presence of an air pocket encountered by the airplane during the filming process. This air pocket caused a sudden change in the altitude of the airplane which made it impossible to establish this model on the plotter. If the plotter used in this project had been equipped with a Z-motion (on individual projectors), it would probably have been possible to clear this model. Fortunately, sufficient information was obtained from the two adjoining models so that this particular model was not needed.

## Vertical Control

Vertical control for every stereoscopic model is required. The vertical control is needed in the absolute orientation procedure so that

the plane of the model can be made parallel to the reference surface. Since a plane is determined by three points, technically only three properly distributed vertical control points are needed to level a model. However, to serve as a check, four or five vertical control points are normally established. The distribution of vertical control points used on the research project is shown in figure 5.

There are two general procedures used in establishing vertical control. In one method the vertical control points are established before the aerial photographs are taken. In the other method the vertical control points are obtained after the aerial photographs have been taken. This latter method appears easier and more efficient because the photographs themselves are used to select vertical control points that are easily recognized. Also, control points are selected so that they can serve more than one stereoscopic pair; hence, the number of control points is kept to a minimum.

It is best to locate vertical control points in relatively flat areas. This helps to minimize errors that occur during the leveling of a model when the floating dot is not placed exactly on the same spot as the level rod is placed during the field work. Another important criteria in choosing vertical control points is to select them in such a manner that shadows are not cast. This is another definite advantage of using the aerial photographs to choose the vertical control points because the aerial photographs clearly show any shadows that are cast at the time of photography.

All vertical control points were selected from the aerial photographs. The elevations of these control points were measured to the nearest 0.01 foot by means of a self-leveling level. The survey level notes were kept

in standard form with a code number to identify each control point. These code numbers were marked on the photographs and all corresponding elevations were marked on the back of each photograph. This procedure expedited the leveling process during absolute orientation.

Seven stereo models were used to cover the area of this research project. These seven models required 22 vertical control points to satisfy the leveling requirements for the Kelsh Plotter. The 22 vertical control points were established in approximately 7.5 hours by a three man survey party. Approximately one hour was required to predetermine the location of these control points.

## Preparation of Base Manuscript

The manuscript for this project was plotted on stable drafting cloth. This tracing cloth had a polyester film base which makes it less susceptible to expansion and shrinkage caused by temperature and humidity changes. All plotting on the manuscript was performed at a scale of one-inch equals 50 feet.

The centerline of the proposed highway and all horizontal control points (flagged centerline stations) were carefully drawn on the manuscript. The corresponding stations were marked beside each of the target points. This made the "scaling of the model" during the absolute orientation much easier. This was because "scaling the model" was now simply a matter of shifting the stereoscopic model until the target images cast by the platen were superimposed with the previously plotted flags.

The next step after the centerline and all horizontal control points had been drawn on the base manuscript was to draw the proposed highway right-of-way lines on the base manuscript. This was accomplished by using

as a reference the construction plans of the research project area furnished by the Indiana State Highway Commission. However, these highway right-of-way lines could also have been established by photogrammetric means. Briefly, this could be accomplished by photogrammetrically plotting a ground profile and cross-section along the proposed centerline of the road. The final grade of the roadway could then be established. Knowing the final grade of the road and having the cross-section data available, the construction limits of the project could be established. The right-of-way width could then be determined by making sure that enough land was acquired to contain the construction limits. Of course, other criteria such as minimum right-of-way requirements for certain type roads and the damages resulting to remaining property, etc., would have to be considered, but this information could be obtained without additional surveying work.

## Photogrammetric Compilation

After the preparatory data had been drawn on the base manuscript, the manuscript was ready for the photogrammetric plotting. The initial plotting effort was primarily for the purpose of plotting the existing property lines of that property crossed by the proposed highway right-of-way. It should be emphasized that all photogrammetric plotting of the property lines must normally be performed in conjunction with deed descriptions, subdivision plats, or other legal documents available that might possibly help determine the location of the property lines. Because slightly different problems were encountered in the plotting of the urban and rural areas, the photogrammetric plottings of these areas will be discussed separately.

## Urban Area

Probably the most frequent indication of the proximity of a property line on the aerial photographs is the existing fence line. One of the obvious problems associated with the use of fence lines to show an existing property line, is the fact that fences are not located on every property. For example, in urban areas, many front property lines are not shown by fences. Likewise, many side yard fences are lacking. Frequently, in place of side yard fences there occurs a row of trees or a cluster of bushes or shrubs. These tree rows, bushes, shrubs, etc. are possibly an indication of a property line, but are not considered to be nearly as accurate or as dependable as fence lines. Another approximate indication of a property line is the tonal difference that exists in the aerial photograph patterns of two adjoining yards. This tonal difference may be caused by the yards having different grass types and/or by the lawns being mowed at different times. The mowing of the lawn at different times allows the grass to become longer in one of the yards and also possibly dryer thus imparting a different photo-tone.

Paved streets can be an aid in front yard property line locations. The paved streets can be easily determined on large scale aerial photographs and easily plotted on a base manuscript. The paved street itself often does not directly indicate a property line, but the property line or street right-of-way line usually can be located a definite distance from the edge of the street or from the edge of the curb. Subdivision plats give sufficient information such that the street right-of-way lines can be plotted by simply scaling certain distances from the pavement.

In some instances the street right-of-way line on one side is easily discernible on the aerial photographs, but the right-of-way line on the other side is not. In this case, if the total right-of-way width is known, the unknown right-of-way line is easily established by scaling. Again, the needed information may be obtained from subdivision plats.

Some cities have certain standard engineering procedures which are an aid in the location of property lines. For example, in some cities the utility and telephone poles and the fire hydrants are located a certain distance within the street right-of-way. In some cities, the backs of sidewalks fronting a street are placed so that one edge of the sidewalk represents the street right-of-way line. Information of this nature, of course, varies from city to city and must be determined in each particular area.

In this research project, the location of street right-of-way lines for unpaved streets was much more difficult than the location of right-of-way lines for paved streets. On the unimproved roads, the side ditch and surrounding area blended with the road itself. On gravel roads the stone was often pushed and shoved beyond or less than the actual limits of the road. These factors made the accurate location of the road right-of-way on the stereoscopic model much more difficult. Possible indications of the right-of-way, other than the road itself, were the ends of private driveways and sidewalks. It was observed that private concrete or asphalt driveways were often built within the limits of private property. Thus, the ends of driveways were a possible indication of the street right- of-way line. Similarly, private sidewalks and retaining walls were indications of the street right-of-way line. Many of these indications of

property lines might not be reliable, especially when used individually. However, when all things had been considered (including subdivision plats, legal descriptions, etc.) and these showed close agreement, there was a good possibility that a fairly accurate solution had been obtained.

### Rural Areas

In rural areas, the fence line was also the best indication of the property line when related to official records. Here, again, the problem of fences not occurring on every property arose. The problem of lack of fences occurred most frequently in low swampy areas and in other places where the land was of little value. Even when the fences were present it was often difficult to determine their exact location because of the weeds and vines. Sometimes these vines growing on the fences would cast a dense, even shadow. In this instance, the plotting of a line at the base of this shadow gave a good location of the fence line; thus, a fairly good indication of the property line.

Variations in crops and variations in the use of particular fields show quite readily on aerial photographs. In some cases, the visible differences in pattern and photo-tone is a possible indication of a property line. Of course, this is only an approximate indication but it can, in many instances, prove most helpful. Tree and shrub rows are also used as approximate indicators.

### Cultural Features

It was necessary to plot all structures, streets, private drives, sidewalks, utility poles, the larger trees and shrubs, and all other pertinent cultural features that would affect the cost of the right-of-way. The roofs of all structures were plotted rather than the sides of

the structures. For obvious reasons, the structures determined by photogrammetric means generally showed larger dimensions than the dimensions of the same structures determined by standard procedures. This did not pose any serious problems with regard to the accuracy of the location of structures for right-of-way purposes. It did, however, make the comparison of the location of various structures as determined by both field and photogrammetric methods somewhat more difficult.

The methods of determining this information in the field requires that right angle measurements be made to all structures and that the base dimensions of the structures be determined. This information is deciphered by a draftsman in the office and plotted in its designated position. Photogrammetric plotting eliminates the necessity of most field measurements and considerably lessens the amount of drafting time required.

## Measuring Phase

After the plotting was completed, the amount of land that was to be acquired from each property owner was determined. It also was necessary to determine the total property owned and the amount of property remaining after the acquisition by the Indiana State Highway Commission. The amount of property remaining was further subdivided into the amount remaining on the right of the proposed road and the amount remaining on the left of the proposed road. This information was essential to the appraiser in determining the severance damage occurring to the remaining property and in determining the amount to be paid for the acquired land.

The various land areas mentioned above were calculated by two different methods. The first method utilized a planimeter. The planimeter was circumscribed about each particular area marked on the base manuscript

from three to five times and the average value recorded. All planimeter readings were obtained to the nearest 0.01 square-inch and converted to acres. The approximate time to plot and calculate the various areas required was 12 hours.

The second method of determining these areas was by scaling from the base manuscript. If the shape of the area to be determined was approximately rectangular, the opposite sides of the rectangle could be scaled and the average values used to determine the area. If the area was irregularly shaped, but with no curved sides, the area was subdivided into convenient triangles and rectangles. The areas of the individual triangles and rectangles were then determined by scaling procedures and summed to give the area of the original irregularly shaped parcel. If an area had a curved side as one of its boundaries, the scaling method was not used to measure the area. In this case, the planimeter method was employed. All distances were scaled and interpolated to the nearest 0.1 foot.

The comparison of deed descriptions by both field surveying and photogrammetric methods was not directly possible. To circumvent this problem it was decided to compare the available data which would later be used to write the deed descriptions.

For deed descriptions based on the centerline it was essential to know: 1) the station where the property line and centerline intersect, 2) the distance to the right or the left of the centerline of every intersection of the right-of-way line and property line, and 3) the station of every break or change in distance from the centerline to the right-of-way line. In the photogrammetric procedures all information was obtained by scaling from the photogrammetrically plotted base manuscript.

The data pertinent in the writing of metes and bounds descriptions were the distance from the centerline and the station on the centerline of every right-of-way corner. It was necessary to measure all distances at right angles to the centerline. This was accomplished by sliding a right triangle along the centerline until one edge of the triangle coincided with the point to be measured. A mark was then made on the centerline. The distance from the mark to the point was carefully scaled giving the right angle distance needed. The distance from the mark to a known station on the centerline was also carefully scaled giving the centerline station of the point.

# ANALYSIS AND RESULTS

## Areas

In all highway right-of-way surveys it is necessary to determine certain pertinent areas. The most important area is the area necessary for acquisition. Other areas which are of value in the acquisition of highway right-of-way are the total area of the property from which the acquisition is being made and the area that is remaining after the acquired portion is subtracted from the total area. The remaining areas are divided into the area remaining on the left of the highway right-of-way and the area remaining on the right of the highway right-of-way. All these areas had been determined by the Indiana State Highway Commission and tabulated on the highway construction plans.

In this project, all these areas are plotted on the base manuscript by photogrammetric means. These areas are then measured by two different methods. These methods are the planimeter method and the scaling method. The results of measurements of area by planimetering, scaling, and as determined by the Indiana State Highway Commission are tabulated in table 1.

Table 1 shows that of the 68 areas calculated by both the planimeter and scaling methods there are no variations between the two methods greater than 0.01 acre. Thirty-eight of the 68 areas measured the same by both scaling and planimetering. The other 30 measurements vary by only 0.01 acre. This definitely indicates that, with the degree of accuracy

TABLE 1

PHOTOGRAMMETRIC MEASUREMENT OF AREAS

| | R/W Needed (Acres) | | | Total Owned (Acres) | | | Remaining Area Left of R/W (Acres) | | | Remaining Area Right of R/W (Acres) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | |
| Parcel No. | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling |
| 17 | 7.77 | 7.76 | 7.77 | 7.77 | 7.76 | 7.77 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 4.85 | 4.85 | 4.86 | 6.47 | 6.38 | 6.39 | 1.51 | 1.40 | 1.41 | 0.11 | 0.12 | 0.12 |
| 37 | 3.29 | 3.29 | -- | 5.86 | 5.81 | 5.80 | 2.27 | 2.21 | 2.22 | 0.30 | 0.31 | 0.30 |
| 47 | 1320 sq ft | 1430 sq ft | 1444 sq ft | 0.61 | 0.56 | 0.56 | 0 | 0 | 0 | 0.58 | 0.53 | 0.54 |
| 77 | 3.98 | 3.95 | -- | 32.47 | X | X | 0 | 0 | 0 | 28.49 | X | X |
| 97 | 3.28 | 3.28 | 3.28 | 31.32 | X | X | 0 | 0 | 0 | 28.04 | X | X |
| 8 | 3.09 | 3.07 | 3.08 | 18.39 | X | X | 5.68 | X | X | 9.52 | X | X |
| 18 | 2.28 | 2.29 | 2.30 | 3.62 | 3.61 | 3.61 | 0.75 | 0.70 | 0.69 | 0.57 | 0.62 | 0.62 |
| 28 | 0.16 | 0.16 | 0.16 | 0.23 | 0.24 | 0.25 | 0 | 0 | 0 | 3300 sq ft | 3580 sq ft | 3587 sq ft |
| 38 | 0.99 | 0.98 | 0.98 | 1.58 | 1.55 | 1.55 | 0.34 | 0.34 | 0.34 | 0.24 | 0.23 | 0.23 |
| 48 | 0.13 | 0.14 | 0.14 | 0.22 | 0.22 | 0.22 | 0 | 0 | 0 | 3270 sq ft | 3295 sq ft | 3320 sq ft |
| 58 | 0.14 | 0.14 | 0.14 | 0.22 | 0.22 | 0.22 | 0 | 0 | 0 | 3355 sq ft | 3400 sq ft | 3324 sq ft |

TABLE 1 (continued)

| | R/W Needed (Acres) | | | Total Owned (Acres) | | | Remaining Area Left of R/W (Acres) | | | Remaining Area Right of R/W (Acres) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | | State Hwy. | Photogrammetry | |
| Parcel No. | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling | Comm. | Planimeter | Scaling |
| 68 | 0.21 | 0.22 | 0.22 | 0.21 | 0.22 | 0.22 | 0 | 0 | 0 | 0 | 0 | 0 |
| 78 | 2500 sq ft | 2383 sq ft | 2440 sq ft | 0.22 | 0.22 | 0.22 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0 |
| 88 | 0.55 | 0.54 | 0.55 | 0.87 | 0.86 | 0.86 | 0.16 | 0.17 | 0.16 | 0.16 | 0.15 | 0.15 |
| 98 | 0.55 | 0.54 | 0.55 | 0.87 | 0.85 | 0.86 | 0.16 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 |
| 9 | 0.55 | 0.57 | 0.57 | 0.87 | 0.90 | 0.90 | 0.16 | 0.17 | 0.17 | 0.16 | 0.16 | 0.16 |
| 19 | 1.11 | 1.08 | 1.08 | 1.74 | 1.68 | 1.68 | 0.32 | 0.33 | 0.33 | 0.31 | 0.27 | 0.27 |
| 29 | 0.57 | 0.58 | 0.57 | 0.87 | 0.88 | 0.87 | 0.14 | 0.14 | 0.14 | 0.16 | 0.16 | 0.16 |
| 39 | 0.58 | 0.61 | 0.60 | 0.87 | 0.89 | 0.88 | 0.13 | 0.13 | 0.12 | 0.16 | 0.16 | 0.16 |
| 49 | 0.23 | 0.21 | 0.20 | 0.41 | 0.41 | 0.40 | 0.18 | 0.20 | 0.20 | 0 | 0 | 0 |
| 59 | 0.81 | 0.81 | 0.80 | 0.81 | 0.81 | 0.80 | 0 | 0 | 0 | 0 | 0 | 0 |
| 69 | 0.12 | 0.12 | 0.13 | 0.41 | 0.42 | 0.42 | 0 | 0 | 0 | 0.29 | 0.30 | 0.29 |

– Contained Curved Boundary, Could Not be Scaled

X Parcel Limits Beyond Photographic Coverage

required, there is no appreciable difference in the planimeter and scaling methods of measuring areas. Because it is much less time consuming to measure the same areas by the scaling method than by the planimeter method, the scaling method is preferred. However, if the boundary being measured contains a curved segment, the planimeter method is employed because of the difficulty of scaling on a curved boundary.

The area which is needed for highway right-of-way acquisition as determined both by Indiana State Highway Commission personnel and by photogrammetric methods is shown in table 2. This table gives the difference between the photogrammetric and Indiana State Highway Commission area determinations in either 0.01 acre or square-feet. This table also gives the percent variation which is determined by dividing the difference between the photogrammetric and Indiana State Highway Commission area determinations by the Indiana State Highway Commission area determination of the area for right-of-way acquisition. This variation is not considered the error in photogrammetric measurement because the areas calculated by Indiana State Highway Commission personnel may possibly be in error.

It is observed (table 2) that six of the 23 individual parcels determined by the planimeter method (column 6) vary from Indiana State Highway Commission determinations by more than four percent. Five of the six largest variations involve areas of 0.23 acre or less (columns 1, 2, and 3). There are five of the 21 parcels determined by the scaling method (column 7) that vary from Indiana State Highway Commission determinations by more than four percent. All five of these involve areas of 0.23 acre or less. As expected, the largest variations occur among the smaller areas measured. With regard to accuracy, this indicates that photogrammetric techniques may be more applicable to rural areas than to urban

TABLE 2

COMPARISON OF RIGHT-OF-WAY FOR ACQUISITION

| Parcel No. | Right of Way Needed for Acquisition (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter 2 - 1 = 4 | Scaling 3 - 1 = 5 | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17 | 7.77 | 7.76 | 7.77 | -0.01 | 0 | -0.13 | 0.00 |
| 27 | 4.85 | 4.85 | 4.86 | 0 | +0.01 | 0.00 | 0.21 |
| 37 | 3.29 | 3.29 | X | 0 | X | 0.00 | X |
| 47 | 1320 sq ft | 1430 sq ft | 1444 sq ft | + 110 sq ft | + 124 sq ft | +8.35 | +9.40 |
| 77 | 3.98 | 3.95 | X | -0.03 | X | -0.76 | X |
| 97 | 3.28 | 3.28 | 3.28 | 0 | 0 | 0.00 | 0.00 |
| 8 | 3.09 | 3.07 | 3.08 | -0.02 | -0.01 | -0.65 | -0.33 |
| 18 | 2.28 | 2.29 | 2.30 | +0.01 | +0.02 | +0.44 | +0.88 |
| 28 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0.00 | 0.00 |
| 38 | 0.99 | 0.98 | 0.98 | -0.01 | -0.01 | -1.01 | -1.01 |
| 48 | 0.13 | 0.14 | 0.14 | +0.01 | +0.01 | +7.78 | +7.78 |
| 58 | 0.14 | 0.14 | 0.14 | 0 | 0 | 0.00 | 0.00 |
| 68 | 0.21 | 0.22 | 0.22 | +0.01 | +0.01 | +4.76 | +4.76 |

TABLE 2 (continued)

| Parcel No. | Right-of-Way Needed for Acquisition (Acres) Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Variation (Acres) Planimeter 2 - 1 = 4 | Variation (Acres) Scaling 3 - 1 = 5 | Percent Variation Planimeter $\frac{4}{1} = 6$ | Percent Variation Scaling $\frac{5}{1} = 7$ |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 78 | 2500 sq ft | 2383 sq ft | 2440 sq ft | - 117 sq ft | - 60 sq ft | -4.68 | -2.40 |
| 88 | 0.55 | 0.54 | 0.55 | -0.01 | 0 | -1.82 | 0.00 |
| 98 | 0.55 | 0.54 | 0.55 | -0.01 | 0 | -1.82 | 0.00 |
| 9 | 0.55 | 0.57 | 0.57 | +0.02 | +0.02 | +3.64 | +3.64 |
| 19 | 1.11 | 1.08 | 1.08 | -0.03 | -0.03 | -2.70 | -2.70 |
| 29 | 0.57 | 0.58 | 0.57 | +0.01 | 0 | +1.76 | 0.00 |
| 39 | 0.58 | 0.61 | 0.60 | +0.03 | +0.02 | +5.17 | +3.44 |
| 49 | 0.23 | 0.21 | 0.20 | -0.02 | -0.03 | -8.70 | -13.02 |
| 59 | 0.81 | 0.81 | 0.80 | 0 | -0.01 | 0.00 | -1.23 |
| 69 | 0.12 | 0.12 | 0.13 | 0 | +0.01 | 0.00 | +8.33 |

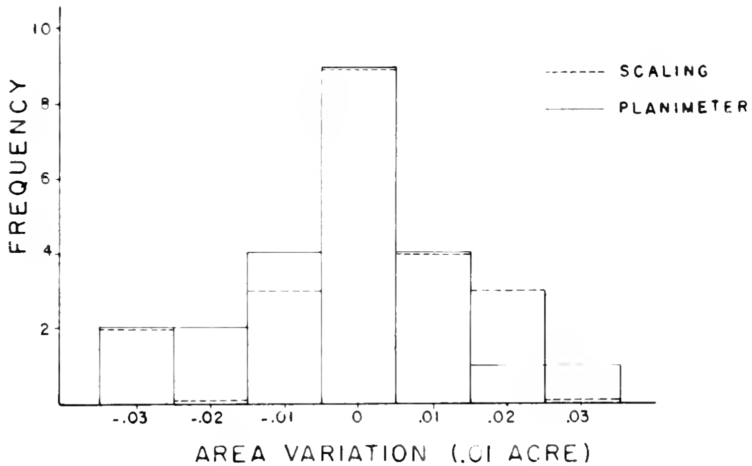
X Contained Curved Boundary, Could Not Be Scaled

areas. This is not only because of the fact that smaller percent variations occur among the larger plots, but also because rural lands are less valuable and do not generally require as high a degree of accuracy of measurement.

The frequency tabulation and frequency polygon of the differences in areas needed for right-of-way acquisition as determined by both photogrammetric (scaling and planimeter) and Indiana State Highway Commission methods are shown in figure 7. This figure is determined from the information given in table 2. The maximum difference in areas between the two methods is 0.03 acre. This maximum difference occurs in three of the 23 areas measured by the planimeter method and in two of the 21 areas measured by the scaling method. Figure 7 also shows that nine of the areas measured by both the planimeter and scaling methods have zero variation, and that 17 of the 23 planimeter areas and 16 of the 21 scaling areas vary by 0.01 acre or less. The magnitude and frequency of these variations indicate very good agreement between the photogrammetric and field survey methods of determining right-of-way acquisition.

The total area owned by each property owner from which land has to be acquired for the proposed highway is shown in table 3. This table shows the difference in areas (0.01 acre) between the total areas as obtained by the Indiana State Highway Commission and the same areas determined by the photogrammetric (scaling and planimeter) methods. This table also gives the percent variation which is determined by dividing the difference between the photogrammetric and Indiana State Highway Commission area determinations by the Indiana State Highway Commission area determination of the total area owned.

| VARIATION | FREQUENCY | |
|---|---|---|
| (.01 ACRE) | PLANIMETER | SCALING |
| -.03 | 2 | 2 |
| -.02 | 2 | 0 |
| -.01 | 4 | 3 |
| 0.00 | 9 | 9 |
| .01 | 4 | 4 |
| .02 | 1 | 3 |
| .03 | 1 | 0 |
| RANGE | TOTAL | TOTAL |
| .06 | 23 | 21 |




FREQUENCY POLYGON OF AREA VARIATION OF RIGHT-OF-WAY TO BE ACQUIRED

FIGURE 7

TABLE 3

COMPARISON OF TOTAL AREA OF INDIVIDUAL PARCELS

| Parcel No. | Total Area Owned (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter 2 - 1 = 4 | Scaling 3 - 1 = 5 | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17 | 7.77 | 7.76 | 7.77 | -0.01 | 0 | -0.13 | 0.00 |
| 27 | 6.47 | 6.38 | 6.39 | -0.09 | -0.08 | -1.38 | -1.24 |
| 37 | 5.86 | 5.81 | 5.80 | -0.05 | -0.06 | -0.85 | -1.02 |
| 47 | 0.61 | 0.56 | 0.56 | -0.05 | -0.05 | -8.20 | -8.20 |
| 77 | 32.47 | X | X | X | X | X | X |
| 97 | 31.32 | X | X | X | X | X | X |
| 8 | 18.39 | X | X | X | X | X | X |
| 18 | 3.62 | 3.61 | 3.61 | -0.01 | -0.01 | -0.28 | -0.28 |
| 28 | 0.23 | 0.24 | 0.25 | +0.01 | +0.02 | +4.35 | +8.70 |
| 38 | 1.58 | 1.55 | 1.55 | -0.03 | -0.03 | -1.90 | -1.90 |
| 48 | 0.22 | 0.22 | 0.22 | 0 | 0 | 0.00 | 0.00 |
| 58 | 0.22 | 0.22 | 0.22 | 0 | 0 | 0.00 | 0.00 |
| 68 | 0.21 | 0.22 | 0.22 | +0.01 | +0.01 | +4.76 | +4.76 |

TABLE 3 (continued)

| Parcel No. | Total Area Owned (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter 2 - 1 = 4 | Scaling 3 - 1 = 5 | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 78 | 0.22 | 0.22 | 0.22 | 0 | 0 | 0.00 | 0.00 |
| 88 | 0.87 | 0.86 | 0.86 | -0.01 | -0.01 | -1.15 | -1.15 |
| 98 | 0.87 | 0.85 | 0.86 | -0.02 | -0.01 | -2.30 | -1.15 |
| 9 | 0.87 | 0.90 | 0.90 | +0.03 | +0.03 | +3.45 | +3.45 |
| 19 | 1.74 | 1.68 | 1.68 | -0.06 | -0.06 | -3.45 | -3.45 |
| 29 | 0.87 | 0.88 | 0.87 | +0.01 | 0 | +1.15 | 0.00 |
| 39 | 0.87 | 0.89 | 0.88 | +0.02 | +0.01 | +2.30 | +1.15 |
| 49 | 0.41 | 0.41 | 0.40 | 0 | -0.01 | 0.00 | -2.44 |
| 59 | 0.81 | 0.81 | 0.80 | 0 | -0.01 | 0.00 | -1.24 |
| 69 | 0.41 | 0.42 | 0.42 | +0.01 | +0.01 | +2.44 | +2.44 |

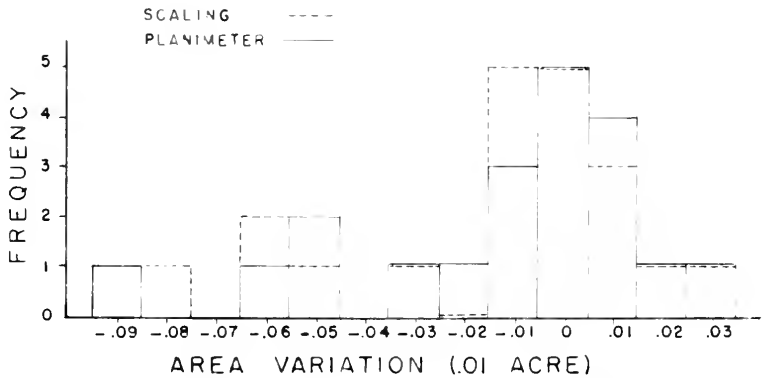
X Parcel Limits Beyond Photographic Coverage

The percent variation column in table 3 shows relatively small differences. One of the 20 areas determined by the planimeter method and two of the 20 areas determined by the scaling method have variations greater than five percent. The maximum variations are 8.2 and 8.7 percent. The largest variation generally occurs for the smaller areas again indicating that photogrammetric techniques may be more applicable to rural areas.

The frequency tabulation and frequency polygon of the differences between the total areas listed for the Indiana State Highway Commission and the total areas determined photogrammetrically is shown in figure 8. This table shows that 12 of the 20 areas determined by the planimeter method and 13 of the 20 areas determined by the scaling method vary by 0.01 acre or less. There are four total areas for both the planimeter and scaling methods which vary from Indiana State Highway Commission quantities by more than 0.05 acre. These differences generally occur for large areas; hence, the percent variations are not excessively large. Table 3 and figure 8 indicate good agreement between the photogrammetric determinations and the Indiana State Highway Commission listings of the total areas of each property involved in right-of-way acquisition.

The total areas listed by the Indiana State Highway Commission are not calculated, but are taken directly from the deed descriptions. The actual determination of total area (owned by each property owner) by field surveying methods is a tremendous undertaking and economically unfeasible for highway right-of-way surveying. At present, deed descriptions furnish this information, but occasionally the deed descriptions lack this information or are of such an age that some of the areas given are unreliable. By means of photogrammetry, the total areas of most parcels can be determined fairly easily, and can be used as a check on the deed description information.

| VARIATION (.01 ACRE) | FREQUENCY | |
|---|---|---|
| | PLANIMETER | SCALING |
| −.09 | 1 | — |
| −.08 | — | 1 |
| −.06 | 1 | 2 |
| −.05 | 2 | 1 |
| −.03 | 1 | 1 |
| −.02 | 1 | — |
| −.01 | 3 | 5 |
| 0 | 5 | 5 |
| .01 | 4 | 3 |
| .02 | 1 | 1 |
| .03 | 1 | 1 |
| RANGE .12 | TOTAL 20 | TOTAL 20 |




FREQUENCY POLYGON OF AREA VARIATION OF TOTAL AREA OWNED

FIGURE 8

Not all of the total areas can be determined by photogrammetry because some of the boundaries extended beyond the limits of the photographs. In this project 20 of the 23 areas are determined by photogrammetric means. However, with respect to table 1, it is shown that most of the parcels in the supposedly rural part of the study are much smaller than the rural areas that normally are encountered. The problem of not being able to determine the total area owned is encountered more frequently when rural areas with large size farms prevail. The main purpose of determining the total areas of each property owner involved is to give some idea of what affect the highway acquisition will have on the remaining part. In most instances, if the farms are relatively large, the amount of land acquired for the highway will be relatively small and an accurate determination of the total area owned is unnecessary.

In this project, all section corners are located outside the coverage of the photographs. This is a definite disadvantage because of the valuable reference which the section corner provides. A possible remedy to this problem is the use of smaller scale photographs. However, this means sacrificing the accuracy which the larger scale photographs provide, and is not feasible for this type project.

The area remaining to the left of the right-of-way acquired from each property is shown in table 4. Table 4 shows the differences between the photogrammetric and Indiana State Highway Commission determination of the areas. This table also gives the percent variation which is determined by dividing the difference between the photogrammetric and Indiana State Highway Commission area determinations by the Indiana State Highway Commission area determination of the area remaining left of the highway right-of-way.

TABLE 4

COMPARISON OF AREA REMAINING LEFT OF RIGHT-OF-WAY

| Parcel No. | Remaining Area Left of R/W (Acres) Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Variation (Acres) Planimeter 2 - 1 = 4 | Variation (Acres) Scaling 3 - 1 = 5 | Percent Variation Planimeter $\frac{4}{1} = 6$ | Percent Variation Scaling $\frac{5}{1} = 7$ |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 27 | 1.51 | 1.40 | 1.41 | -0.11 | -0.10 | -7.20 | -6.63 |
| 37 | 2.27 | 2.21 | 2.22 | -0.06 | -0.05 | -2.64 | -2.20 |
| 47 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 8 | 5.68 | X | X | X | X | X | X |
| 18 | 0.75 | 0.70 | 0.69 | -0.05 | -0.06 | -6.68 | -8.01 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 38 | 0.34 | 0.34 | 0.34 | 0 | 0 | 0.00 | 0.00 |
| 48 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 58 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 68 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |

TABLE 4 (continued)

| Parcel No. | Remaining Area Left of R/W (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter 2 - 1 = 4 | Scaling 3 - 1 = 5 | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 78 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0.00 | 0.00 |
| 88 | 0.16 | 0.17 | 0.16 | +0.01 | 0 | +6.25 | 0.00 |
| 98 | 0.16 | 0.15 | 0.16 | -0.01 | 0 | -6.25 | 0.00 |
| 9 | 0.16 | 0.17 | 0.17 | +0.01 | +0.01 | +6.25 | +6.25 |
| 19 | 0.32 | 0.33 | 0.33 | +0.01 | +0.01 | +3.13 | +3.13 |
| 29 | 0.14 | 0.14 | 0.14 | 0 | 0 | 0.00 | 0.00 |
| 39 | 0.13 | 0.13 | 0.12 | 0 | -0.01 | 0.00 | -7.70 |
| 49 | 0.18 | 0.20 | 0.20 | +0.02 | +0.02 | +11.10 | +11.10 |
| 59 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 69 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |

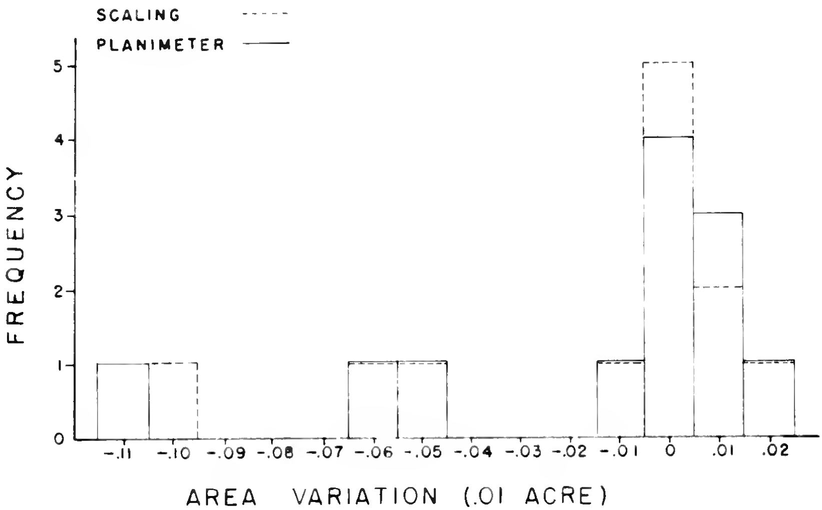
X Parcel Limits Beyond Photographic Coverage

It is shown in table 4 that six of the 12 areas determined by the planimeter method vary from the Indiana State Highway Commission methods by more than five percent. Five of the 12 areas determined by the scaling method vary more than five percent. The maximum variation for both methods is 11.1 percent. Of the six areas determined by the planimeter method with variations greater than five percent, four are areas involving less than 0.20 acre. Of the five areas determined by the scaling method with variations greater than five percent, three involve areas of less than 0.20 acre. This indicates that the largest percent variations occur for the smaller areas measured; hence, photogrammetric techniques may be more applicable to rural areas.

The frequency tabulation and frequency polygon of the differences in area remaining to the left of the proposed highway right-of-way is shown in figure 9. This table shows that eight of the 12 remaining areas determined for both the planimeter and scaling methods vary by 0.01 acre or less. The frequency of these small variations indicate good agreement between the photogrammetric and Indiana State Highway Commission determination of areas remaining on the left of the right-of-way to be acquired.

The area remaining to the right of the right-of-way acquired from each property owner is shown in table 5. Table 5 shows the differences between the photogrammetric and Indiana State Highway Commission determinations of these areas. This table also gives the percent variation which is determined by dividing the difference between the photogrammetric and Indiana State Highway Commission area determinations by the Indiana State Highway Commission area determinations of the area remaining on the right of the highway right-of-way.

| VARIATION | FREQUENCY | |
|---|---|---|
| (.01 ACRE) | PLANIMETER | SCALING |
| -.11 | 1 | — |
| -.10 | — | 1 |
| -.06 | 1 | 1 |
| -.05 | 1 | 1 |
| -.01 | 1 | 1 |
| 0 | 4 | 5 |
| .01 | 3 | 2 |
| .02 | 1 | 1 |
| RANGE .13 | TOTAL 12 | TOTAL 12 |




FREQUENCY POLYGON OF AREA VARIATION
LEFT OF RIGHT-OF-WAY
FIGURE 9

TABLE 5

COMPARISON OF AREA REMAINING RIGHT OF RIGHT-OF-WAY

| Parcel No. | Remaining Area Right of R/W (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter 2 - 1 = 4 | Scaling 3 - 1 = 5 | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 27 | 0.11 | 0.12 | 0.12 | +0.01 | +0.01 | +9.10 | +9.10 |
| 37 | 0.30 | 0.31 | 0.30 | +0.01 | 0 | +3.33 | 0.00 |
| 47 | 0.58 | 0.53 | 0.54 | -0.05 | -0.04 | -8.62 | -6.90 |
| 77 | 28.49 | X | X | X | X | X | X |
| 97 | 28.04 | X | X | X | X | X | X |
| 8 | 9.52 | X | X | X | X | X | X |
| 18 | 0.57 | 0.62 | 0.62 | +0.05 | +0.05 | +8.77 | +8.77 |
| 28 | 3300 sq ft | 3580 sq ft | 3587 sq ft | + 280 sq ft | + 287 sq ft | +8.48 | +8.70 |
| 38 | 0.24 | 0.23 | 0.23 | -0.01 | -0.01 | -4.17 | -4.17 |
| 48 | 3270 sq ft | 3295 sq ft | 3320 sq ft | + 25 sq ft | + 50 sq ft | +0.77 | +1.53 |
| 58 | 3355 sq ft | 3400 sq ft | 3324 sq ft | + 45 sq ft | - 31 sq ft | +1.34 | -0.93 |

TABLE 5 (continued)

| Parcel No. | Remaining Area Right of R/W (Acres) | | | Variation (Acres) | | Percent Variation | |
|---|---|---|---|---|---|---|---|
| | Indiana State Highway Comm. | Photogrammetry Planimeter | Photogrammetry Scaling | Planimeter $2 - 1 = 4$ | Scaling $3 - 1 = 5$ | Planimeter $\frac{4}{1} = 6$ | Scaling $\frac{5}{1} = 7$ |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 68 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 78 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 88 | 0.16 | 0.15 | 0.15 | -0.01 | -0.01 | -6.25 | -6.25 |
| 98 | 0.16 | 0.16 | 0.15 | 0 | -0.01 | 0.00 | -6.25 |
| 9 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0.00 | 0.00 |
| 19 | 0.31 | 0.27 | 0.27 | -0.04 | -0.04 | -12.90 | -12.90 |
| 29 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0.00 | 0.00 |
| 39 | 0.16 | 0.16 | 0.16 | 0 | 0 | 0.00 | 0.00 |
| 49 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 59 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 69 | 0.29 | 0.30 | 0.29 | +0.01 | 0 | +3.45 | 0.00 |

X Parcel Limits Beyond Photographic Coverage

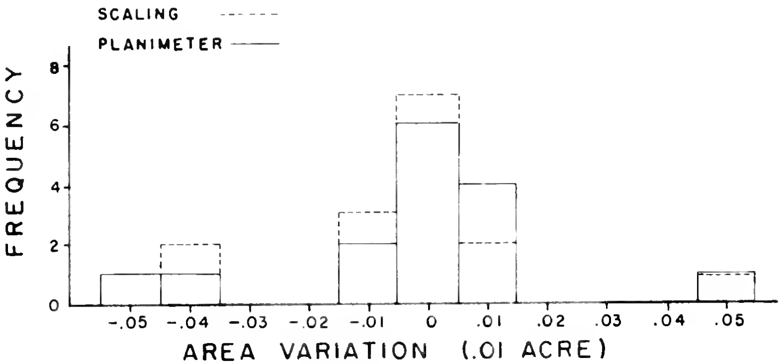
It is shown in table 5 that six of the 15 areas determined by the planimeter method have variations greater than five percent. Seven of the 15 areas determined by the scaling method have variations greater than five percent. The maximum variation for both methods is 12.9 percent. Of the six largest percent variations determined by the planimeter method, four involve areas of less than 0.31 acre and all six involve areas of 0.57 acre or less. Of the seven largest percent variations determined by the scaling method, five involve areas of 0.31 acre or less and all seven involve areas of 0.57 acre or less. This indicates that the largest percent variations occur for the smaller areas measured; hence, photogrammetric techniques may be more applicable to rural areas.

The frequency tabulation and frequency polygon of the differences in areas remaining to the right of the proposed highway right-of-way is shown in figure 10. This table shows that 12 of the 15 remaining areas determined for both the planimeter and scaling methods vary by 0.01 acre or less. The size and frequency of these variations indicate good agreement between the photogrammetric and Indiana State Highway Commission determination of areas remaining on the right of the right-of-way to be acquired.

## Cultural Data

An analysis of the accuracy of location of cultural objects was accomplished by comparing the location of the cultural objects determined photogrammetrically with the location of the same cultural objects determined by field survey methods. On the construction plans furnished by the Indiana State Highway Commission each cultural object was located by a station on the centerline and a distance from the centerline. This

| VARIATION (.01 ACRE) | FREQUENCY PLANIMETER | FREQUENCY SCALING |
|---|---|---|
| -.05 | 1 | – |
| -.04 | 1 | 2 |
| -.03 | – | – |
| -.02 | – | – |
| -.01 | 2 | 3 |
| 0 | 6 | 7 |
| .01 | 4 | 2 |
| .02 | – | – |
| .03 | – | – |
| .04 | – | – |
| .05 | 1 | 1 |
| RANGE .10 | TOTAL 15 | TOTAL 15 |




FREQUENCY POLYGON OF AREA VARIATION
RIGHT OF RIGHT-OF-WAY

FIGURE 10

same information was obtained from the photogrammetric base manuscript for each cultural object and a comparison was then made with the centerline stations and distances given on the construction plans. Structures with over-hanging roofs were not used in the comparisons because, in the field methods, the sides of structures were determined to locate the structure and, in photogrammetric methods, the roof was used to locate the structure.

Table 6 lists a comparison of centerline stations and table 7 lists a comparison of distances from the centerline for various cultural objects determined by both methods. The data used in the comparisons represent only a random sample of the total data. Table 6 shows that the average absolute variation between the centerline stations of objects determined by both methods is 0.87 feet. Table 7 shows that the average absolute variation of distances to the cultural objects determined by both methods is 0.7 feet. These small variations indicate that the location of cultural objects by photogrammetric means at the scale used in this project are generally of sufficient accuracy for right-of-way surveys.

## Deed Descriptions Based on Centerline

The stations, determined photogrammetrically, of the fence line intersection with the centerline are scaled from the base manuscript (scale one-inch equals 50 feet). However, since the deed descriptions are not available, these centerline stations for the Indiana State Highway Commission method have to be determined from another source. On the construction plans a centerline station and a distance from the centerline are given for each fence corner. With this information known it is possible by interpolation to determine the station where the fence line intersects the proposed

TABLE 6

COMPARISON OF CENTERLINE STATIONS OF CULTURAL OBJECTS

| Photogrammetric | Indiana State Highway Commission | Difference |
|---|---|---|
| +39.0 | +38.7 | 0.3 |
| +47.2 | +47.0 | 0.2 |
| +23.5 | +23.0 | 0.5 |
| +02.2 | +02.0 | 0.2 |
| +02.9 | +04.0 | 1.1 |
| +15.8 | +14.0 | 1.8 |
| +40.0 | +42.0 | 2.0 |
| +26.4 | +24.0 | 2.4* |
| +49.6 | +48.5 | 1.1 |
| +91.5 | +91.0 | 0.5 |
| +82.5 | +84.0 | 1.5 |
| +55.0 | +55.0 | 0.0 |
| +59.2 | +59.0 | 0.2 |
| +60.2 | +60.0 | 0.2 |
| | | 12.2 |

Average Absolute Variation = $\frac{12.2}{14}$ = 0.87 feet

* Maximum Variation = 2.4 feet

TABLE 7

COMPARISON OF DISTANCES TO CULTURAL OBJECTS

| Photogrammetric | Indiana State Highway Commission | Difference |
|---|---|---|
| 17.0 | 17.0 | 0.0 |
| 8.0 | 7.5 | 0.5 |
| 12.5 | 13.0 | 0.5 |
| 75.0 | 76.0 | 1.0 |
| 28.0 | 29.5 | 1.5* |
| 67.0 | 68.0 | 1.0 |
| 96.0 | 95.5 | 0.5 |
| 57.0 | 56.0 | 1.0 |
| 10.0 | 10.0 | 0.0 |
| 50.0 | 49.0 | 1.0 |
| | | 7.0 |

Average Absolute Variation = $\frac{7.0}{10}$ = 0.7 feet

* Maximum Variation = 1.5 feet

centerline. Normally, the Indiana State Highway Commission does not perform this much work to determine this station; the Commission would simply scale this station directly from the construction plans (one-inch equals 100 feet). For the purposes of this study the interpolation procedure seems to provide more accurate comparisons.

It is not necessary to compare the distances to the right-of-way lines since these distances are the same for both the photogrammetric and the Indiana State Highway Commission methods. The right-of-way widths shown on the construction plans are used on the photogrammetric base manuscript in order that area comparisons can be made of the same areas.

The stations at which the property line intersects the centerline are shown in table 8 for both the photogrammetric and the Indiana State Highway Commission methods. The absolute value of the difference in feet is also shown in column 3 for each station. The sum of this column divided by the number of values used gives an average absolute variation of 0.89 feet. This, again, does not mean that the photogrammetric readings are in error by 0.89 feet, it only means that the photogrammetric readings vary from the Indiana State Highway Commission readings by an average of 0.89 feet. When it is considered that the Indiana State Highway Commission normally scales this centerline station from construction plans (scale one-inch equals 100 feet), and that in the scaling process an error of the above magnitude can easily occur, this value (0.89 feet) does not seem to be an unnecessarily large variation. In view of the present Indiana State Highway Commission methods of determining this centerline station and in view of the magnitude of the average variation, the comparison of photogrammetrically obtained data can be considered to be in good agreement.

TABLE 8

COMPARISON OF INTERSECTION OF CENTERLINE

WITH PROPERTY LINE (feet)

| Photogrammetric | Indiana State Highway Commission | Variation |
|---|---|---|
| +21.1 | +20.1 | 1.0 |
| +46.9 | +46.0 | 0.9 |
| +11.0 | +12.2 | 1.2 |
| +58.5 | +58.0 | 0.5 |
| +50.8 | +52.2 | 1.4 |
| +51.7 | +49.8 | 1.9* |
| +00.9 | +01.6 | 0.7 |
| +41.3 | +42.0 | 0.7 |
| +01.8 | +01.0 | 0.8 |
| +62.5 | +61.5 | 1.0 |
| +82.0 | +82.0 | 0.0 |
| +01.4 | +02.0 | 0.6 |
| +59.3 | +61.0 | 1.7 |
| +81.1 | +82.5 | 1.3 |
| +04.1 | +03.5 | 0.6 |
| +62.4 | +62.4 | 0.0 |
| | | 14.3 |

Average Absolute Variation = $\frac{14.3}{16}$ = 0.89 feet

* Maximum Variation = 1.9 feet

Deed Descriptions Based on Metes and Bounds

To make a metes and bounds description in a manner similar to that of the Indiana State Highway Commission it is necessary to determine the station on the centerline and the distance from the centerline of every right-of-way corner. This information is determined by scaling from the base manuscript. Similarly, the distances and stations of every property corner can be established on the base manuscript. Since this information is given directly on the Indiana State Highway Commission construction plans, the comparison is made between these data and the data obtained from the photogrammetric procedures. The stations on the centerlines of these property corners are shown for both the photogrammetric and Indiana State Highway Commission methods in table 9.

The average absolute variation (in feet) for the centerline stations of the property corners is 1.35 feet. It was emphasized previously that all plotting should normally be accomplished with the aid of any deed descriptions, subdivision plats, and any other documents that might be of assistance. However, nearly this entire project was plotted without the aid of this additional information. The main purpose of this is to prevent the use of any prejudiced information. Table 9 shows that the average absolute difference between stations is 1.35 feet. This table also shows that six of the 20 stations vary by more than two feet. Upon rechecking these six property corners on the base manuscript, it was found that these property corners were the most difficult to detect. However, there were property lines nearby which were accurately located photogrammetrically and which could have been used as a check on these property corners. The check could have been made by scaling the distances given

TABLE 9

COMPARISON OF CENTERLINE STATIONS OF PROPERTY CORNERS

| Photogrammetric | Indiana State Highway Commission | Variation |
|---|---|---|
| +99.1 | +99.0 | 0.1 |
| +08.8 | +08.0 | 0.8 |
| +76.2 | +77.0 | 0.8 |
| +84.5 | +88.0 | 3.5* |
| +55.5 | +57.0 | 1.5 |
| +63.5 | +66.0 | 2.5 |
| +96.7 | +98.0 | 1.3 |
| +05.0 | +06.0 | 1.0 |
| +78.2 | +78.0 | 0.2 |
| +85.5 | +86.0 | 0.5 |
| +66.0 | +65.0 | 1.0 |
| +36.6 | +39.0 | 2.4 |
| +45.5 | +45.0 | 0.5 |
| +96.8 | +99.6 | 2.8 |
| +04.9 | +04.0 | 0.9 |
| +15.1 | +15.0 | 0.1 |
| +47.5 | +44.6 | 2.1 |
| +56.2 | +55.0 | 1.2 |
| +47.0 | +46.0 | 1.0 |
| +55.2 | +58.0 | 2.8 |
| | | 27.0 |

Average Absolute Variation = $\frac{27.0}{20}$ = 1.35 feet

* Maximum Variation = 3.5 feet

on the subdivision plat from the reliable property line plotted. In all probability this procedure would have decreased the amount of variation.

A comparison is also made of the distances determined both photogrammetrically and by field surveying methods to the property corners. These comparisons are listed in table 10. From this table the average absolute variation between the two methods is calculated to be 0.82 feet. The differences in these distances is fairly consistent with the maximum variation being 1.5 feet. There is some question whether an average variation of this size is acceptable in metes and bounds descriptions. However, since the Indiana State Highway Commission does not turn right angles with a transit to measure each distance (economically unfeasible), the Commission's measurements may be somewhat in error and the variation of 0.82 feet may not be excessively large.

Because of the magnitude of the average absolute variation of the differences in centerline stations (1.35 feet) and also because of the magnitude of the average absolute variation of the distance to the centerline (0.82 feet) comparison of photogrammetric and Indiana State Highway Commission determinations of data needed for metes and bounds descriptions may be considered in fair agreement.

TABLE 10

COMPARISON OF DISTANCES TO PROPERTY CORNERS

| Photogrammetry | Indiana State Highway Commission | Difference |
|---|---|---|
| 156.5 | 157.5 | 1.0 |
| 157.0 | 157.5 | 0.5 |
| 156.5 | 155.5 | 1.0 |
| 157.0 | 157.5 | 0.5 |
| 156.7 | 156.5 | 0.2 |
| 157.0 | 156.5 | 0.5 |
| 157.1 | 156.0 | 1.1 |
| 156.6 | 156.5 | 0.1 |
| 158.0 | 156.5 | 1.5* |
| 156.0 | 155.5 | 0.5 |
| 158.0 | 159.0 | 1.0 |
| 156.0 | 155.0 | 1.0 |
| 158.7 | 159.6 | 0.9 |
| 155.5 | 154.5 | 1.0 |
| 158.6 | 159.5 | 0.9 |
| 155.5 | 154.5 | 1.0 |
| 159.4 | 159.2 | 0.2 |
| 155.0 | 155.6 | 0.6 |
| 160.2 | 161.5 | 1.3 |
| 154.0 | 152.5 | 1.5 |
| | | 16.3 |

Average Absolute Variation = $\frac{16.3}{20}$ = 0.82 feet

* Maximum Variations = 1.5 feet

# SUMMARY AND CONCLUSIONS

## Evaluation of Study Conditions

In reviewing the conditions under which this project was performed, it was seen that there were certain limitations which had an affect upon this study. One of the limiting factors was the element of time. The research was performed at uneven intervals and at short periods of time. This fact made it impossible to compare the time consumed by photogrammetric methods of making a right-of-way survey with time consumed by field methods of making a right-of-way survey. A comparison of the costs of these two methods was also impractical because the aerial photographs were only used for right-of-way purposes. In actual practice, the photographs would be employed by a highway department for many different studies and surveys.

Another limiting factor involved was the problem of comparing the results of photogrammetric methods with the results of field survey methods. This was difficult because there were no commonly accepted accuracy limits for right-of-way field survey methods. One reason for this was the fact that it was impossible and entirely uneconomical to measure every angle of every property acquisition with a transit. Because of this, distances at approximate right angles must often be relied upon for accuracy.

## Conclusions

From the analysis and results of this study, it may be concluded that:

1. The planimeter and scaling methods used in measuring the various areas gave results of similar accuracy. All 68 areas measured by both methods agreed within 0.01 acre. The scaling methos was to be preferred when the area did not contain a curved boundary because it was much less time consuming. The planimeter method was preferred when curved boundaries were involved.
2. The areas required for acquisition as determined by the photogrammetric methods were generally in good aggrement with the same areas determined by Indiana State Highway Commission procedures. Seventeen of 23 areas measured by the planimeter method and 16 of 21 areas measured by the scaling method varied by 0.01 acre or less.
3. The total areas of each land owner determined photogrammetrically were in good agreement with the areas given on the deed descriptions. Nineteen of the 20 areas determined by the planimeter method and 18 of the 20 areas determined by the scaling method had variations less than five percent.
4. The areas remaining to the left of the acquired right-of-way determined photogrammetrically were in good aggrement with the same areas determined by Indiana State Highway Commission procedures. Eight of the 12 areas determined by both the planimeter and the scaling methods varied 0.01 acre or less.
5. The areas remaining to the right of the acquired right-of-way determined photogrammetrically were in good agreement with the same areas determined by Indiana State Highway Commission

procedures. Twelve of 15 areas determined by both the planimeter and the scaling methods varied by 0.01 acre or less.

6. The percent variations for the various areas were generally larger for the smaller areas measured.
7. The photogrammetric methods were more applicable in rural areas than in urban areas.
8. The cultural features could generally be located more rapidly by photogrammetric methods, at the scale used in this project, and to an accuracy generally acceptable for highway right-of-way acquisition. The average absolute variation between the center-line stations of cultural objects determined by both methods was 0.87 feet. The average absolute variation of distances to the cultural objects determined by both methods was 0.7 feet.
9. The comparison of photogrammetric data needed for the writing of deed descriptions based on the centerline was generally in good agreement with the same data determined by field survey methods. The average absolute variation between the centerline stations was 0.89 feet.
10. The comparison of photogrammetric data needed for the writing of deed descriptions based on metes and bounds descriptions was generally in fair agreement with the same data determined by field survey methods. The average absolute variation in the centerline stations of property corners as determined by both methods was 1.35 feet. The average absolute variation in distances to the property corner was 0.82 feet.
11. A double projection plotter of the Kelsh type was satisfactory, at the scale used in this project, for plotting the data needed for right-of-way acquisition.

# RECOMMENDATIONS

Due to the favorable results of this project, it is recommended that further study be undertaken of a more extensive nature. A more extensive study should include: a minimum length of two miles; an area including a complete interchange; an area partially rural and partially urban; a road partially tangent and partially curved; and aerial photographs obtained at different flying heights in order to provide different scales for accuracy comparisons. The area should also have previously been carefully surveyed by precise field survey methods in order to provide an accurate base for the photogrammetric comparisons.

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